Chapter 4: Nonroad Mobile Inventory Development

LESSON GOAL

Demonstrate, through successful completion of the chapter review exercises, a general understanding of EPA's NONROAD model. Also, the student should be able to describe the approaches for estimating PM emissions from aircraft, commercial marine vessels, and locomotives.

STUDENT OBJECTIVES

When you have mastered the material in this chapter, you should be able to:

1. Describe the source categories and pollutants that are included in the NONROAD model.

2. Explain the methodology used by the NONROAD model to estimate emissions.

3. Define the source categories that comprise the aircraft category.

4. Explain the methodology used to estimate aircraft emissions in the NEI and how a state or local agency can improve on those results.

5. Identify the source categories that comprise the commercial marine vessel category.

6. Explain the methodology used to estimate commercial marine vessel emissions in the NEI and how a state or local agency can improve on those results.

7. Identify the source categories that comprise the locomotive category.

8. Explain the methodology used to estimate locomotive emissions in the NEI and how a state or local agency can improve on those results.

Chapter 4: Nonroad Mobile Inventory Development

The discussion of EPA's National Mobile Inventory Model (NMIM) that was presented in Chapter 3 is also applicable to the nonroad category, but will not be repeated here. It should be noted that aircraft, railroad, and commercial marine vessel inventories are not included in the NONROAD model and are estimated independently.

4.1 NONROAD Model

The latest version of EPA's NONROAD model can be accessed at this web address:

www.epa.gov/otaq/nonrdmdl.htm.

This web site contains documentation, a user's guide, as well as technical reports to describe the sources and development of all the default input values (e.g., equipment populations, geographic allocations, growth factors, and emission rates).

4.1.1 Sources

Table 4-1 lists the source categories that are included in the NONROAD model. The four-digit source classification code (SCC) generally denotes the engine type, or fuel that is used in the nonroad equipment. There are two exceptions where the four-digit SCC denotes the equipment type instead of the engine type: the recreational marine and railroad maintenance categories.

Table 4-1. Engine Types Included in the NONROAD Model

SCCs	Type
2260xxxxxx	2-Stroke Gasoline
2265xxxxxx	4-Stroke Gasoline
2267xxxxxx	Liquefied Petroleum Gasoline (LPG)
2268xxxxxx	Compressed Natural Gas (CNG)
2270xxxxxx	Diesel
2282xxxxxx	Recreational Marine
2285xxxxxx	Railroad Maintenance

Table 4-2 lists the 12 different equipment categories denoted by the seven-digit SCC that are included in the NONROAD model. Within each of these categories there are multiple applications that are specified at the 10-digit SCC level.

Table 4-2. Equipment Categories Included in the NONROAD Model

Equipment Category (7-digit SCC denotes equipment)	
Airport Ground Support	Logging
Agricultural	Recreational Marine Vehicles
Construction	Recreational Equipment
Industrial	Oil Field
Commercial	Underground Mining
Residential/Commercial Lawn and Garden	Railway Maintenance

4.1.2 Pollutants

The pollutants included in the NONROAD model are PM_{10} and $PM_{2.5}$ (representing primary PM), CO, NO_x, VOC, SO_2 and CO_2. Ammonia is not a direct output of the NONROAD model, but it can be estimated based on fuel consumption estimates that are obtained from the model and EPA emission factors derived from light-duty onroad vehicle emission measurements. In addition to exhaust pollutants, the NONROAD model estimates evaporative VOC components from crankcase emissions, spillage, and vapor displacement.

4.1.3 Emission Calculations

The NONROAD model calculates exhaust emissions by assuming that they are dependent on equipment activity. The model takes into account a number of measures of equipment activity, including how many hours per year the equipment is used, the load factor at which the engine is operating, the average rate of horse power of the engine, and the equipment population (i.e., how many pieces of equipment are in use). These equipment activity measures are multiplied by emissions factors in tons per horsepower-hour to obtain emission estimates as shown in Equation 4-1.

Equation 4-1. NONROAD Model Emission Equation

$$I_{exh} = E_{exh} * A * L * P * N$$

where: I_{exh} = Exhaust emissions (tons/year)
E_{exh} = Exhaust emission factor (ton/hp-hr)
A = Equipment activity (hours/year)
L = Load factor (proportion of rated power used on average basis)
P = Average rated power for modeled engines (hp)
N = Equipment population

Values for the equipment activity measures are generally obtained from a market engine research firm that conducted telephone surveys of equipment owners and operators to generate default values for the different equipment categories. However, there are some exceptions that are described in the documentation for the NONROAD model.

The emission factors are dependent on the engine type as well as the engine size, or horsepower. Future year emission controls or standards are reflected in revised emission rates, so that as older engines are scrapped and new engines replace them, revised emission rates are applied to the new engines to reflect the standards that they need to meet.

SO_2, CO_2 and evaporative VOC emissions are based on fuel consumption. In the NONROAD model, PM_{10} is assumed to be equivalent to total PM and for gasoline and diesel engines, $PM_{2.5}$ is assumed to be 0.92 times PM_{10}. For liquefied petroleum gas (LPG) and compressed natural gas engines, all PM is assumed to be less than $PM_{2.5}$.

4.1.4 Geographic and Temporal Allocation

Because there are no estimates of county level populations, the NONROAD model estimates those populations using surrogate indicators. The model starts with national or state level equipment populations (either by equipment type or horsepower range) and allocates them to the county level by using surrogate indicators that correlate with nonroad activity for a specific equipment type.

The NONROAD model also accounts for temporal variations in activity. The temporal profiles vary by month and depend on the equipment category and the geographic region of the country. The model contains typical weekday and weekend day activity profiles by equipment category, however, those do not vary by region.

4.1.5 Improving the NONROAD Results

One way to improve EPA's latest 2002 model results is to specify local fuel characteristics and the ambient temperatures specific to the area being modeled. Also, if possible, the NONROAD default activity inputs should be replaced with state or local data. However, it can be resource intensive to obtain reasonable estimates to replace the default values. In order to obtain this data it would be necessary to perform a local survey of equipment owners and users.

Another way to improve the model results is to obtain local information to improve the geographic allocation (i.e., going from state to county). Obtaining local data used for the temporal profiles can also improve the model results.

Finally, another approach to improve the model results is to focus on priority categories and obtain better data for those categories. For example, for fine PM, priority categories would be diesel construction, diesel farm, diesel industrial, gasoline lawn and garden, and gasoline recreational marine.

4.2 AIRCRAFT

The SCCs representing the aircraft categories that have been historically reported in the NEI are listed with their definitions in Table 4-3. The activity data used for aircraft are known as a landing and takeoff operations, or LTO. Emissions are estimated by applying emission factors to the LTO data that are either specific to an aircraft or engine type. If the make-up of the aircraft fleet is unknown, fleet averages are available to be applied to the emission factors.

Table 4-3. Aircraft SCC

SCC	Aircraft Type	Definition
2275020000	Commercial Aircraft	Aircraft used for scheduled service to transport passengers, freight, or both
2275050000	General Aviation	Aircraft used on an unscheduled basis for recreational flying, personal transportation, and other activities, including business travel
2275060000	Air Taxis	Smaller aircraft operating on a more limited basis to transport passengers and freight
2275001000	Military Aircraft	Aircraft used to support military operations

The LTO cycle consists of different modes including: the approach, taxi idle in, taxi idle out, take off, and climb out. The operation time in each of these modes is dependent on the aircraft category, meteorological conditions, as well as how the airport is operating (e.g., the length of time waiting to take off). In addition, there can be substantial variations in these modes from airport to airport. Because different emission rates result when the aircraft are operating in each of these modes, it is important to consider all of these factors in estimating emissions from aircraft.

4.2.1 NEI Method

The NEI estimated emissions for commercial aircraft by using national-level FAA LTO data by aircraft type and emission rates from the Emissions and Dispersion Modeling System (EDMS) version 4.0. The NEI estimated emissions from the general aviation, air taxi, and military aircraft categories by also using national LTO data, however, data was not available for specific aircraft types within each of the aircraft categories. Consequently, emissions for these three categories were estimated by multiplying total LTO by an emission factor as shown in Equation 4-2.

Equation 4-2. NEI Method – General Aviation, Air Taxi, and Military Aircraft

$$\text{National Emissions}_{c,p} = \text{National LTO}_c * EF_{c,p}$$

where: LTO = Landing and take-off operations
EF = Emission factor
c = Aircraft category
p = criteria pollutant

Using PM as an example, the emission factors are LTO-based and represent a fleet average emission factor for the general aviation, air taxi, and military aircraft categories. Table 4-4 presents these PM emission factors. The $PM_{2.5}$ primary emissions are estimated, as they are for many combustion sources, by applying a particle-sized multiplier of 0.92 to the PM_{10}.

Table 4-4. LTO-Based PM Emission Factors

Category	PM Emission Factor (lbs/LTO)
General Aviation	0.2367
Air Taxi	0.60333
Military Aircraft	0.60333

Once national emissions are calculated for the four aircraft categories, the NEI allocates them to the county level based on airport level LTO data. This is shown in Equation 4-3. Using La Guardia airport as an example, the NEI assumes that a fraction of the total LTO is assigned to La Guardia, and the emissions calculated from this allocation are assigned to the corresponding county.

Equation 4-3. Emissions Allocation for Aircraft Categories

$$\text{Airport Emissions}_{c,p,x} = \text{National Emissions}_{c,p} * AF_{c,p,x}$$

where: AF = allocation factor
x = airport (e.g., La Guardia)
c = Aircraft category
p = criteria pollutant

More information on the NEI methodology for estimating emissions from aircraft categories can be found at the following web address: ftp://ftp.epa.gov/EmisInventory/finalnei99ver3/criteria/documentation/nonroad/99nonroad_voli_oct2003.pdf.

4.2.2 General Approach

Although it may be acceptable to rely upon the NEI data for smaller airports in an area, a bottom up inventory should be developed for the larger airports. There are seven steps for developing an aircraft inventory for a specific airport.

- Step 1 - Determine the mixing height to be used to define the LTO cycle. The mixing height is important because above the mixing height, emissions are not expected to contribute much to ground level pollutant concentrations.

- Step 2 - Define the fleet make-up for the airport.

- Step 3 - Determine airport activity in terms of the number of LTO by aircraft and their associated engine-type.

- Step 4 - Select emission factors for each engine model that is associated with the aircraft fleet at the airport being inventoried (Instead of using defaults that EDMS may apply for a specific aircraft type).

- Step 5 – Estimate the time-in-mode for the aircraft fleet at the airport.

- Step 6 - Calculate the emissions (based on the aircraft LTO data, the emission rates for each aircraft engine model, and the time-in- mode data).

- Step 7 – Aggregate the emissions across aircraft to obtain a total for the airport.

4.2.3 NEI Improvements

Developing an emissions inventory for a local airport involves determining the engine types associated with the local aircraft types. This data is an improvement over the assumptions used in the NEI for the commercial aircraft category. In addition, developing information on climb-out, take-off, approach time, and taxi idle times will be an improvement over the defaults used in the NEI.

Because the current version of EDMS does not include PM emission rates, EPA recommends that the few PM emission factors that are available in the 1992 version of the Mobile Sources Procedures document be matched to the aircraft engines in the local fleet as best as possible. EPA is aware of this limitation and work is underway to try to get better data on PM emission factors for commercial aircraft. Some regional inventories have looked at using emission factor ratios to develop the PM emission rates for commercial aircraft. Specifically, the ratio based on the PM_{10} and NO_X emission factor ratios for air toxics was applied to the commercial aircraft NO_X emissions.

For the other categories (general aviation, air taxis, and military aircraft) the NEI can be improved by obtaining local LTO estimates (i.e., the LTO not covered by the FAA data). Obtaining this data from smaller airports that may not be reporting to the FAA would be an improvement. The same is true for military bases, although the heightened security over the last couple years has made it harder to obtain data from military operations.

Another improvement is to obtain information on the aircraft/engine types that comprise the fleet for these other categories. If data on the mix of aircraft types in a fleet are available, engine specific emission factors or EDMS could be used to estimate emissions. Finally, the NEI can be improved by maintaining the latitude/longitude of the airport so the emissions are not “smeared” across the entire county.

4.3 COMMERCIAL MARINE VESSELS

The SCCs representing the commercial marine vessel categories that are currently used in the NEI are listed in Table 4-5. This includes diesel activity for ships in port and underway, as well as residual or steamships for those two categories.

Table 4-5. Commercial Marine Vessel SCC

SCC	Type
2280002100	Diesel, In Port
2280002200	Diesel, Underway
2280003100	Residual, In Port
2280003200	Residual, Underway

4.3.1 NEI Method

The NEI methodology for commercial marine vessels is a top down method that splits national diesel and residual emissions into port and underway components. The methodology makes assumptions about what portion of the activity for both diesel and residual ships takes place in ports and what portion takes place underway (i.e., away from ports or on their way between ports). These are allocated separately since port activity surrounds a port area, while underway covers a larger area such as along a river system. Both port and underway emissions are assigned to counties, however, port emissions are assigned to a single county in a port area.

More information on the NEI methodology for estimating emissions from the commercial marine vessel categories can be found at the following web address: ftp://ftp.epa.gov/EmisInventory/finalnei99ver3/criteria/documentation/nonroad/99nonroad_voli_oct2003.pdf.

4.3.2 NEI Improvements

One approach to improving the NEI emission estimates for the commercial marine vessel category is to review the spatial allocation of commercial marine emissions that is included in the NEI. The NEI method looks at port traffic for the 150 largest ports in the United States and only allocates those emissions. However, there are additional ports that are not accounted for in the allocation method. Identifying smaller ports that are not accounted for in the NEI would be an improvement.

Another approach to improving the NEI method is to allocate port emissions to the appropriate counties. Port emissions in the NEI are being assigned to a single county in the port area. While that may hold for some ports (e.g., deep sea ports or coastal ports) where the port activity is centered on one county, there are other ports along the Mississippi and the Ohio Rivers that span multiple counties and even state boundaries. Assigning these port emissions to the appropriate counties and states is another way to improve the NEI results.

Another approach to improving the NEI results is to conduct a bottom-up inventory by obtaining activity estimates at the state or local level from the DOT or Port Authority. This can include data on fuel consumption, as well as data to define the actual categories and characteristics of the vessels in terms of the number, size and horsepower in each category. Similar to aircraft, there are different emission rates depending on the operating mode of the vessels (i.e., cruising or reduced speed zone, maneuvering or hotelling), so data on the fraction of the time engines are spent in those modes would also be an improvement.

Finally, underway emissions can be improved by using available GIS data to monitor vessel movement.

Equation 4-4 shows the methodology for calculating emissions from commercial marine vessels. It requires data on vessel populations, horsepower, load factor, and the time-in-mode operation. Applying this emission equation with this data will produce a better inventory.

Equation 4-4. Emission Methodology for Commercial Marine Vessels

$$\text{Emissions} = \text{Pop} * \text{HP} * \text{LF} * \text{ACT} * \text{EF}$$

where: Pop = Vessel Population or Ship Calls
HP = Average Power (hp)
LF = Load Factor (fraction of available power)
ACT = Activity (hours)
EF = Emission Factor (g/hp-hr)

4.3.3 Activity Profiles

In 1999 EPA completed two studies that provide commercial marine activity profiles for select ports, and present a method for an inventory preparer to allocate detailed time-in-mode activity data from a typical port to another similar port. These studies are *Commercial Marine Activity for Deep Sea Ports in the United States* and *Commercial Marine Activity for Great Lake and Inland River Ports in the United States*. The specific variables that are collected for the typical ports in these studies include: 1) the number of vessels in each category, 2) the vessel characterization, including propulsion size (horsepower), capacity tonnage, and engine age, and 3) the number of hours at each time-in-mode associated with cruising, reduced speed zone, maneuvering, and hotelling.

These studies also contain data on the number of trips and the tons of cargo handled by vessel type for the top 95 deep-sea ports and the top 60 Great Lake and inland river ports. Based on the data calculated for a typical port, more detailed activity can be estimated for these ports. These reports also describe how the typical port inventories were developed and how they can be scaled that to a port activity in a specific area.

4.3.4 Emission Factors

Horsepower-based emission factors are available for use with activity data on the number and size of engines. There are also fuel-based emission factors available for use with activity data on fuel consumption. EPA has been performing studies to develop updated emission factors as part of their rulemaking activities, such as the Category 3 engine final rulemaking that was published in 2003.

Table 4-6 presents EPA recommended PM_{10} emission factors that EPA has developed for specific categories of commercial marine engines, on a gram per kilowatt-hour basis for Category 1 and Category 2 engines (i.e., small commercial marine vessel engines).

Table 4-6. Small Commercial Marine Vessel PM_{10} Emission Factors

Engine Category	PM10 [g/kW-hr]
Category 1: 37-75 kW	0.90
Category 1: 75-225 kW	0.40
Category 1: 225+ kW	0.30
Category 2: (5-30 l/cylinder)	0.32

EPA recommended PM_{10} emission factors for the larger engines are listed in Table 4-7. These factors are listed by the different modes of operation.

Table 4-7. Large Commercial Marine Vessel PM_{10} Emission Factors

Mode: Engine	PM10 [g/kW-hr]
Cruise and Reduced Speed Zone: 2-stroke	1.73
Cruise and Reduced Speed Zone: 4-stroke	1.76
Maneuvering: 2-stroke	2.91
Maneuvering: 4-stroke	2.98
Hotelling: 2-stroke	0.32
Hotelling: 4-stroke	0.32
All Modes: Steam Generators	2.49

Emission factors in grams per gallon of fuel consumed are also available from *Procedures for Emissions Inventory Preparation, Volume IV: Mobile Sources,* EPA-450/4-81-026d (Revised), U.S. EPA, OAQPS, July 1989. As with aircraft category, $PM_{2.5}$ emissions from commercial marine vessels are estimated to be 92% of the PM_{10} emissions.

4.4 LOCOMOTIVES

The SCCs representing the locomotive categories that are currently used in the NEI are listed in Table 4-8. This includes larger Class I line haul locomotives that travel through many states, as well as the smaller Class II and III line haul locomotives that tend to operate in a smaller area. The NEI also has information on passenger Amtrak trains, commuter trains, and switchyard operations.

Table 4-8. Locomotive SCC

SCC	Type
2285002006	Diesel Class I Line Haul
2285002007	Diesel Class II/III Line Haul
2285002008	Diesel Passenger (Amtrak)
2285002009	Diesel Commuter
2285002010	Diesel Switchyard Locomotives

4.4.1 NEI Method

The PM emission factors in that are used in the NEI for the line haul and yard operations are listed in Table 4-9.

Table 4-9. NEI Locomotive PM Emission Factors

Type	PM10	PM2.5
Line-Haul	6.7 g/gallon	6.03 g/gallon
Yard	9.2 g/gallon	8.28 g/gallon

The activity data are based on a national estimate of the gallons of distillate fuel oil consumed. This national fuel consumption is allocated among four of the five categories of railroads to develop a national activity value for these four categories (i.e., Class I, Class II/III, Passenger, and Commuter). Switchyard operation activity is estimated by multiplying the national Class I fuel consumption by the estimated line-haul percentage of the total fuel consumption. In other words, the fuel consumption estimates for Class I line-haul locomotives are assumed to include switchyard fuel consumption. This assumption is based on the fact that the larger line-haul railroads are the ones that tend to operate in a switchyard.

The allocation of the activity data to the county level is based on a ratio of county to national rail activity. This rail activity is measured as a product of density (gross tons per mile) for each rail line and mileage for the associated rail line in the county. Mileage for each rail line in the county is measured using a GIS database that is available from the Bureau of Transportation Statistics.

Detailed documentation on the procedures used to develop criteria and HAP pollutant locomotive emission estimates for the 1999 NEI can be found at the following web address:

ftp://ftp.epa.gov/EmisInventory/finalnei99ver3/criteria/documentation/nonroad/99nonroad_voli_oct2003.pdf.

4.4.2 NEI Improvements

The first step in improving the NEI locomotive emission estimates is to examine the NEI data for reasonableness. If the NEI data does not represent emissions in a specific area, more representative fuel consumption at the local or state level should be obtained. Also, because the NEI makes an assumption to estimate switchyard emissions, an improvement could be made by obtaining information on the actual switchyard activity in the study area.

Review Exercises

1. Which of the following types of equipment are denoted by a four-digit SCC instead of the usual seven-digit designation?
   a. Logging
   b. Railroad Maintenance
   c. Underground Mining
   d. Recreational Equipment

2. Which of the following pollutants does **not** have an emission factor included in the NONROAD model?
   a. CO
   b. CO2
   c. Ammonia
   d. VOC

3. Which of the following is a measure of equipment activity that is used by the NONROAD model to estimate exhaust emissions?
   a. Load factor
   b. Horsepower
   c. Equipment population
   d. All of the above

4. For gasoline and diesel engines, the NONROAD model assumes that $PM_{2.5}$ is _______ PM_{10}.
   a. equal to
   b. one half of
   c. 0.08 times
   d. 0.92 times

5. National aircraft emissions in the NEI are allocated to the county level based on _______.
   a. population
   b. airport LTO data
   c. the number of airports
   d. All of the above

6. The first step in estimating aircraft emissions for a specific airport in the NEI involves _______.
   a. estimating the time-in-mode for the aircraft fleet
   b. defining the fleet make-up for the airport
   c. determining the mixing height
   d. determining the number of LTO at the airport

7. The NEI methodology for commercial marine vessels allocates _______ emissions to a single county.
   a. port
   b. underway
   c. both port and underway
   d. neither port nor underway

8. Which of the following is **not** an example of activity data that characterizes a commercial marine vessel?
   a. Propulsion size
   b. Time-in-mode
   c. Capacity tonnage
   d. Engine age

9. The NEI allocates national fuel consumption to develop a national activity for all the locomotive categories **except** _______.
   a. Class I
   b. Passenger
   c. Commuter
   d. Switchyard

10. Which of the following types of data is least likely to be obtained in a survey of a railroad company, especially for smaller companies?
    a. fuel consumption
    b. total miles of track
    c. gross tonnage
    d. number of locomotives

Review Answers

1. b. Railroad Maintenance
2. c. Ammonia
3. d. All of the above
4. d. 0.92 times
5. b. airport LTO data
6. c. determining the mixing height
7. a. port
8. b. Time-in-mode
9. d. Switchyard
10. c. gross tonnage